BELLCOMM, INC.
955 L'ENFANT PLAZA NORTH, S.W. WASHINGTON, D. C. 20024

B69 03104

SUBJECT: Minimizing the Crew Work Day Prior to EVA on the First Lunar Landing Mission - Case 310

DATE: March 3, 1969

FROM: R. E. Driscoll

ABSTRACT

The first lunar landing mission timeline is examined to determine the feasibility of conducting the lunar surface exploration before a required sleep period on the lunar surface. Two plans are developed which utilize a split LM checkout in order to minimize the time required to condition the LM on touchdown day and compress the time interval between touchdown and the start of the extravehicular activity (EVA). The crew awake time at the start of the EVA would be about 10-10.5 hours if either of these plans were used. It may also be feasible to include a real time mission option not to sleep on the lunar surface after the EVA, in which case the crew awake time at LM/CSM docking would be 19.5-20 hours.

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MEMORANDUM FOR FILE

Introduction

The first lunar landing mission (G-1) timeline is currently being reevaluated in order to reduce the length of the lunar module (LM) crew work day prior to the lunar surface extravehicular activity (EVA). Previous timelines have had the LM crew awake some 16 hours prior to the start of an EVA on the lunar surface. Faced with such a situation, it has been proposed that the crew sleep on the lunar surface prior to conducting the EVA. Intrinsically, this is an unattractive procedure for the first lunar landing mission and the mission planners have been requested to modify the timeline to allow EVA before a sleep period on the lunar surface. This memorandum suggests methods whereby not only is it possible to conduct the EVA before scheduling a sleep period on the lunar surface, but it may be feasible to delete the lunar sleep period entirely.

Timeline Evolution

It would be helpful to review, briefly, the evolution of the lunar landing mission timeline, specifically from lunar orbit insertion (LOI) through lunar launch, to identify the major influences.

Initial attempts at defining a lunar landing mission (LLM) timeline concentrated on maximizing the lunar surface exploration portion of the mission. These timelines were constructed using basic vehicle design data, such as the maximum LM active lifetime, and preliminary estimates of task times required to perform given crew activities in order to establish a baseline for future mission planning. These mission plans used the technique of insertion into lunar orbit, checkout of the LM in two or three revolutions, and descent to the lunar surface. Many of the present operational limitations and systems constraints were not identified for this timeline. The crew work/eat/rest cycle was ill defined. As better estimates of crew activity times, mission planning constraints, landing site selection, etc., became available, the timeline was amended. Two of the more significant changes were the inclusion of a sleep period in lunar orbit prior to preparations for LM descent and the adoption of the two burn LOI. The former was specifically added in order to minimize the LM crew awake time prior to the first of two EVA periods. The latter was added to provide a more flexible timeline and to handle possible orbital dispersions. The effect of these two changes lengthened the time in lunar orbit prior to descent from about 7 hours to about 24 hours and insured another SPS burn.

At the Lunar Mission Review in August 1968, it was decided that the first LLM would consist of only one EVA. As the timeline further evolved, the intervals of time between the end of the sleep period in orbit to touchdown to the first opportunity for EVA increased to such an extent that the LM crew required a sleep period before the EVA. The major factors which contributed to the long crew work cycle were: 1) the requirement for two sets of landmark sightings and a docked LM IMU fine alignment; 2) a lengthy time interval between the lunar module pilot (LMP) entry and commander (CDR) entry into the LM; 3) a general increase in the estimated times to perform LM systems checkout; and 4) a two hour interval on the lunar surface checking the LM status before powering down LM systems. The following discussion outlines two plans that can reduce the crew awake time prior to the EVA.

Plan 1 - Split LM Checkout in Lunar Orbit

Figure 1 illustrates a crew timeline from LOI through the first probable launch opportunity after accomplishing the lunar surface objectives, and ascent, rendezvous, and docking. Shown are the major events, approximate periods of MSFN communication coverage, intervals during which the spacecraft are in lunar darkness, and significant activities of each crewman. Also indicated on the figure are numbers which are cross referenced below for additional discussion.

First LM Checkout

One of the main features of the timeline is the first of two LM checkout intervals scheduled, item (1). There are several features connected with the first checkout that require elaboration. First, it is suggested that the crew not don their PGA's for this checkout. This will allow freedom of movement during the transfer and checkout and avoid the time consuming donning and doffing operation.* Secondly, it is suggested that only one crewman enter the LM for this checkout because two men are not needed. The majority of the systems to be checked are

*Current timelines indicate that it requires about 20 minutes per man to don or doff their PGA's and is a serial operation.

normally checked by the LMP and can be adequately handled by one man during the time available. Checks of the primary and abort guidance systems should be deferred until prior to LM/CSM separation when they are really needed. This first checkout is intended to be a comprehensive check of most of the LM systems, primarily the EPS, ECS (partial), communications (both VHF and S-Band), lights, instrumentation system, etc., in order to develop sufficient confidence in these systems to allow minimum re-checking prior to separation. (The total LM power required for these checks is estimated to be less than 60 A-H.) It is also proposed that all possible equipment transfer take place during this interval. (See Appendix A for typical activities.) Thirdly, it is assumed that the probe and drogue remain stowed in the CM. This will facilitate crew reentry into the LM, saving about 10 minutes. The CM pressure and thermal hatch should be in place during the sleep period.

Another important consideration is whether the LM should be left in a partially power-up state or be powered down. This timeline recommends that the LM be powered down. The rationale is twofold. First, leaving the LM powered up presents an unnecessary crew-safety and mission-success risk due to the fact that the LM will not be continuously monitored by MSFN and the crew response time will be lengthy should a detectable problem develop. Secondly, even a partially powered up LM results in a significant power penalty. From Reference 1 the minimum heat load required to insure that the water sublimator will not freeze is 800 BTU/HR which corresponds to a power level of about 260 watts/hour. The water sublimator dry-out power penalty is estimated to be about 560 watts. With proper scheduling, useful system checkouts can be continued during the sublimator dry-out interval. Confidence in the dry-out procedure should be high as the procedure will be carried out twice on the upcoming "D" mission, and on LM-4 and subs the sublimator dry-out can be confirmed by the glycol temperature telemetry measurement (Reference 1).

Command Pilot (CMP) Options

The activity interval for the CMP, item (2), from LOI, to the eat period prior to sleep was intentionally left blank in order to point out a possible mission option regarding simultaneous crew sleep. Simultaneous sleep has been vigorously supported by the C-prime crew. It does present a risk especially in lunar orbit because of non-continuous MSFN communications. If it is decided not to allow simultaneous sleep prior to LM descent, approximately 5.5 hours are available for a CMP sleep period if the LOI maneuver is performed with one SPS burn. The CMP would then have been awake some 14.5 hours or some 7 hours longer than the LM crew at LM touchdown on the lunar surface.

Second Period of LM Checkout

Assuming that simultaneous sleep is allowed, the crew would be awaken by MSFN about 7.5 hours prior to touchdown. This allows about one hour for the LM crew to eat and don their PGA's, item 3. The CMP can wait for a more favorable time for PGA donning, if required at all. Since PGA donning is a serial operation requiring about 20 minutes each, it is suggested that while one LM crewman dons his PGA the other LM crewmen eat. This will allow a forty minute eat period and a twenty minute PGA donning operation to be accomplished in one hour, after which the CM hatch is removed (the probe and drogue having been previously removed and stowed) and the LMP enters the LM.

The timeline (Figure 1) allows about 45 minutes, item 4, between LMP and CDR entry into the LM. This interval is consistent with the present plans for the third LM activation period detailed in the "D" mission flight plan (Reference 2). During this interval the LMP reactivates the LM systems and performs a cursory check of those systems which have been checked out in detail during the first LM entry. The CDR must transfer to the LM prior to the CSM IMU alignment since simultaneous use of the CM optics and tunnel use are not compatible. The CSM IMU alignment, which is assumed to be constrained to be carried out in darkness, is necessary for the landmark sightings, item 5. This set of landmark sightings is done on the next pass over the landing site, about 4 hours prior to touchdown. Note that only one set of landmark sightings are assumed on this timeline. Prior to the C-prime mission, two sets of landmark sightings were deemed necessary. (The first set of sightings was done about 6 hours prior to touchdown.) The primary purpose of the first set was to familiarize the crew with the landing area so that, on the next pass, the landmark could be easily acquired. It also provided MCC-H with a check, to insure that both sightings were on the same landmark. Only the second set of landmark data were to be used, in conjunction with MSFN tracking data, to reduce the size of the LM landing error ellipse. Preliminary indications from the C-prime mission suggest that the acquisition and tracking of landmarks is a relatively simple task. It is however, attitude constraining and time consuming. It also requires that the IMU be aligned prior to the sightings.

Referring to the timeline, this would mean that if two sets of sightings were required an additional IMU alignment would have to be performed at about the time the crew is shown to be waking up. This would force the crew to awake at an earlier time in order to don their PGA's (done in the lower equipment bay). Hence, the second landmark tracking exercise directly impacts the parameter we are trying to minimize, namely, the crew awake time prior to the EVA. A secondary effect would be the probable lack of high bit rate LM telemetry during the period of landmark tracking due to attitude constraints. (The LM steerable antenna pointing is not compatible with the attitude required by the CM optics for landmark tracking in lunar orbit.)

The two-man LM checkout interval, item 6, is about three hours prior to LM/CSM undocking. Again, the time and activities assumed are consistent with those associated with the third LM period of activity on the "D" mission (See Appendix B).

The need for a docked LM IMU fine alignment (using the AOT) is still an open issue. The docked alignment and the undocked alignment after LM separation would provide a gyro drift check prior to the DOI and powered descent maneuvers. However, the docked fine alignment using the AOT is time consuming, would complicate the schedule of crew activities, and would require elaborate procedures to prevent LM RCS plume impingement on the CM thermal coating. MSC is currently examining other means of determining platform drift, prior to the powered descent maneuver. It is assumed herein that a docked alignment using the AOT will not be necessary.

LM/CSM Undocking to Touchdown

The time interval between undocking and touchdown is about 2.5 hours. Typical activities during this period are listed in Appendix C. Very little can be done to reduce this interval since CSM inspection of the LM must be done in daylight, the LM crew must prepare for DOI (includes a LM IMU fine alignment in darkness) and DOI is fixed with respect to the landing site (DOI occurs about one hour prior to touchdown). Thus the crew awake time prior to touchdown is approximately 7.5 hours.

Lunar Surface Timeline

The current lunar surface timeline shows that the nominal staytime is about 22 hours. Of this time, about 5 hours are used, prior to the EVA, for: 1) post-touchdown checks; 2) a simulated LM countdown and liftoff on the next CSM pass; 3) a one hour LM power down and eat period; and 4) a two hour period for EVA preparations. The three hour EVA is followed by a 1.5 hour post EVA interval, wherein the PLSS's are doffed and unneeded equipment is jettisoned, then an eat/sleep/eat period of 10 hours is scheduled. Finally, about 3 hours are spent preparing the LM for lunar ascent. (Lunar ascent to LM/CSM docking require about 4 hours.) Assuming that the crew is awake 7.5 hours prior to touchdown, the EVA would commence using the surface timeline above, with the crew awake some 12.5 hours. This would be within the current ground rule of a 16/8 hour work/rest cycle.

Having concluded that it is feasible to plan to perform the EVA prior to a rest period, the next logical question is, "Is it practical to include in the mission plan a real time decision or option to terminate the lunar stay, after accomplishing the EVA objectives, without a rest period?" (This is not to be confused with an abort decision, which is based on specific system malfunctions, which can occur at anytime.) The probability of using such a real time option is directly related to the length of the crew work day prior to docking and crew transfer to the CSM. In order to enhance this probability, the nominal lunar surface timeline, prior to the EVA, must be reduced and procedures for shortening the nominal timeline after the EVA, should the option be selected, must be developed.

Pre-EVA Timeline

In order to reduce the pre-EVA timeline, a number of currently scheduled activities must be deleted and others must be shortened. Only those activities essential to crew safety should be nominally planned. For example, the current timeline includes as many as four LM IMU alignments, using three of the four alignment options (Reference 3), during the first two hours on the lunar surface. These alignments are done to checkout the various alignment modes, check the IMU drift rates, and performed as part of the simulated countdown sequence. Individually, each of these activities has merit and is a desirable thing to do but collectively they are time consuming and are not essential to crew safety particularly if the powered descent, landing, and post landing checks are nominal. This whole sequence of activities, including the simulated countdown, is performed basically to determine the status of the LM guidance systems and is predicated on the assumption that these systems will be deactivated (to conserve electrical power) about two hours after touchdown and will not be reactivated until the beginning of preparations for ascent. If this assumption is modified somewhat, it is possible to develop a much shorter sequence of activities without compromising crew safety or necessarily incurring an electrical power penalty.* Hence, it is suggested that after the post touchdown checks are completed the LM IMU be realigned and the guidance systems be left in an operate state at least until the EVA is completed. After the alignment a 25 to 30 minute eat period should be scheduled, after which the crew commence preparation for the EVA. If the EVA preparations can be completed in 1.5 hours, rather than the estimated 2 hours, the start of the EVA would be about 2.5 hours after touchdown, with a crew awake time of 10 hours.

* Every hour of pre-EVA time that can be deleted is equivalent to about 3 hours that the guidance systems can remain in the operate state.

The suggested sequence of activities may appear to be too ambitious in light of the current lunar surface timelines. However, it is one that is designed to capitalize upon success and yet does not compromise crew safety in doing so. The stability of the LM on the lunar surface and the status of critical systems are verified prior to any other activity, the MCC-H continuously monitors the LM system status, and the LM is maintained in a posture for ascent. (This sequence is very similar to that proposed by MSC at the LLM Symposium in June 1966, Reference 4.)

The only drawback to this sequence is the probable deletion of rendezvous radar (RR) tracking data on the first CSM pass over the LM. This data was planned to be used by MCC-H for landing site determination. However, MCC-H will still have the following data for determining the LM position on the lunar surface: 1) the LM navigated state; 2) LM attitude and gravity vector data; 3) CSM sextant tracking of the LM; 4) MSFN tracking data; and 5) crew survey data. Reference 3 states that the RR data and sextant data are statistical combined, using different weighting functions, to update the LM position in selenographic coordinate. It is also anticipated that the sextant data will provide the best estimate of the LM position (Reference 3).

It must also be kept in mind that any delay in performing these sequences of activities does not jeopardize crew safety or mission success. It's only effects are to lessen the probability of selecting the real time option of deleting the sleep period on the surface and to possibly shorten the nominally planned 10.5 hour eat/sleep/eat period somewhat.

Post-EVA Timeline

The nominal post-EVA timeline should include a sleep period on the lunar surface. If the real time option not to sleep on the lunar surface is selected, an alternate procedure should be developed to shorten the activities that must be accomplished prior to ascent, in order to minimize the crew work day prior to LM/CSM docking and crew transfer.

A LM in-window launch opportunity occurs about every two hours after touchdown. With the nominal pre-EVA period shortened and the EVA assumed to be 3 hours in duration, the LM crew would be back in the LM about 5.5 hours after touchdown. The first reasonable launch opportunity would then occur 2.5 hours later, or at touchdown plus 8 hours. As mentioned above, the estimated nominal times for the post-EVA activity and ascent preparations are 1.5 and 2.5-3 hours respectively. It also seems advisable to include an eat period prior to liftoff. Hence, about 5 hours of nominal activity time must be compressed into a 2.5 hour interval to meet the first launch opportunity. The reasonableness of reducing the post-EVA activity time of doffing the PLSS and jettisoning unneeded equipment cannot be assessed without crew simulations. If the post-EVA activity can be shortened to about one hour, this would provide about a 30 minute eat interval and a one hour period for ascent preparations. The ascent preparations interval is in fact nominally reduced by at least 30 minutes if the guidance systems are in the operate mode at the outset. A one hour interval for ascent preparations would still be significantly greater than the minimum time to prepare and execute the powered ascent program. Reference 5 estimates this minimum time to be about 17 minutes.

In summary, if the no sleep option is selected and the above recommendations are implemented, the crew awake times at initiation of lunar ascent and docking with the CSM will be 15.5 hours and 19.5 hours, respectively.

Plan 2. <u>Initial Checkout of the LM Prior to LOI</u>

Figure 2 illustrates a crew timeline from about 20 hours prior to LOI through touchdown on the lunar surface. The numbers on the figure are cross referenced below for additional comments.

Item 1, on Figure 2, shows a three hour LM checkout interval occurring prior to the last nominally scheduled mid-course correction. The activities during this period are similar to those discussed in Plan 1. The major difference is that the S-Band steerable antenna will not be deployed to prevent the SM RCS plume from contaminating the steerable antenna thermal control coating. (Once the antenna is unstowed, used and then power removed, the position of the antenna can drift from an acceptable region into the contamination region, Reference 1) As in Plan 1, the LM will be powered down and the probe and drogue remain stowed in the CM. The confidence gained in the LM systems checked during this time should in no way be diminished by the LOI burn. The LM will have been subjected to significantly greater periods of stress during earth launch and TLI, where acceleration levels are about 4 and 1.4 g's, respectively, than the upcoming LOI maneuver, where the maximum acceleration level is less than 1/3 g.

The timing for the last midcourse correction, Figure 2, item 2, will be constrained if this plan is used. Allowing for a seven hour simultaneous sleep period and time to prepare for the LOI maneuver, the latest tolerable time for the correction is about

8.5 hours prior to LOI. Although this is not the most optimum time for the correction (MSC is suggesting 5 hours before LOI) it should be adequate as evidenced by the Apollo 8 mission.

After the sleep period the crew is awakened by the MSFN about 1-1/3 hours prior to LOI. During this interval, Figure 2, item 3, the crew eats, prepares for the LOI burn and the LMP dons his PGA. This allows the LMP to enter the LM immediately after the LOI maneuver. The LOI maneuver, item 4, is assumed to be accomplished with one SPS burn. This is an essential assumption to this plan since LM undocking is scheduled about four hours after LOI. After the LMP enters the LM, item 5, the crew activities are almost identical to those described in Plan 1. The crew has 3-3/4 hours to ready the LM prior to undocking. The total awake time at touchdown is about 8 hours for the easterly landing sites and 8.5 hours for the westerly landing sites. (Plan 1 is not affected by the landing site location since the sleep period in lunar orbit can be adjusted.) Thus the critical activities prior to and following LM separation are standard for either plan and hence should have no impact on crew training. The obvious payoff when Plan 2 is used is a reduction of about fourteen hours of total mission time from Plan 1 and about twenty hours from current flight plans.

Summary

The two plans discussed above can be summarized by comparing them with the timeline presented at the November, 1968 Mission Review (Reference 6). Figure 3 shows the major events and activities of each timeline from shortly before the last scheduled translunar midcourse correction (MCC4) to the nominal LM/CSM docking. Also included are the approximate time durations for the major activities and the overall crew work/rest cycle for each plan.

The November timeline shows that if the EVA were conducted prior to the scheduled sleep period on the lunar surface the crew would be subjected to a 21.5 hour work day. The contributing factorsto this lengthy day are the single phase LM checkout and the activities preceding the EVA on the lunar surface. The crew awake time prior to touchdown and to the start of the EVA would be 11 and 16 hours respectively. Plan 1 reduces these times to about 7.5 and 10 hours by using a split LM checkout and by deleting and compressing non-critical activities after touchdown. Plan 1 also makes it possible to include a real time mission option to terminate the lunar stay after the EVA with a resulting crew awake time at LM/CSM docking of about 19.5 hours. By using the split LM checkout technique the total time in lunar orbit prior to touchdown is reduced by four hours and by shortening the activities prior to the EVA the nominal lunar stay is reduced by two hours.

Plan 2 appears to vary quite drastically with the November and Plan 1 timelines but the individual blocks of activities are almost identical. The first LM checkout is done prior to the last midcourse correction (MCC4) and the sleep period is between the MCC4 and the LOI maneuver rather than in lunar orbit. After this sleep period the crew prepares for and executes the LOI maneuver with one SPS burn. After LOI the LMP enters the LM and all activities are the same as in Plan 1. The crew awake time prior to touchdown is about 8 hours. Although Plan 2 is not as flexible as Plan 1, it does have one asset, namely, a reduction of about 14 hours of total mission time from Plan 1 and 20 hours of total mission time from the November timeline.

R. E. Driscoll

2013-RED-cjz R. E. Driscoll

Attachments
References
Appendices A, B and C
Figures 1, 2 and 3

REFERENCES

1. "CSM/LM Spacecraft Operational Data Book", Volume II, MSC/ASPO, June 1968 and subsequent amendments.

2. "Final Apollo 9 Flight Plan", MSC/FCSD, February 3, 1969.

3. "Apollo Mission Techniques Lunar Landing Mission Ascent Phase", Volume I, Draft, MSC, July 12, 1968.

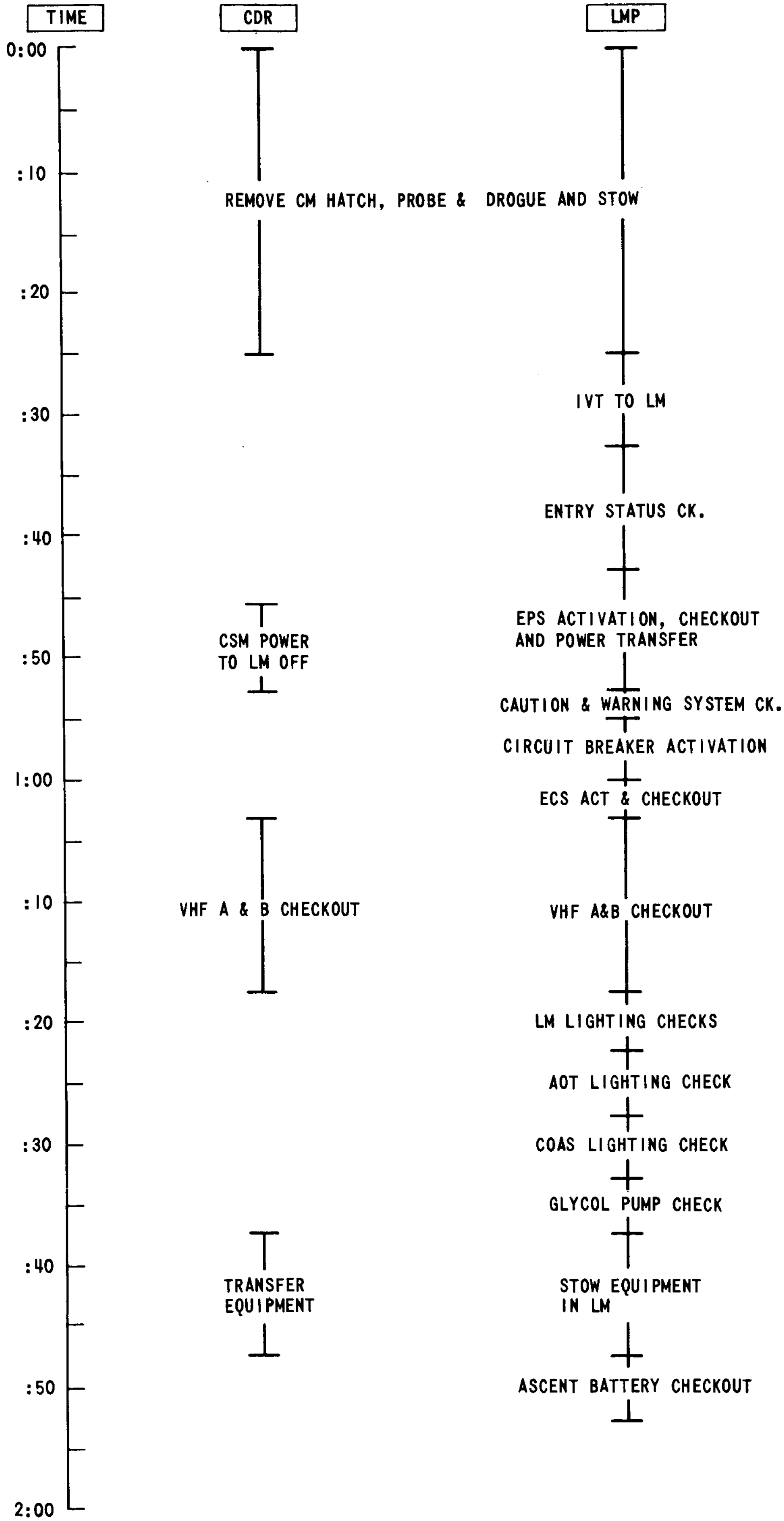
4. "Apollo Lunar Landing Mission Symposium", Volume III, MSC, June 25-27, 1966.

5. "Enclosure 11 to the Minutes of the 31st "G" Flight Operations Plan Meeting", MSC, June 27, 1968.

6. "Mission Review of the First Lunar Landing Extravehicular Activity Meeting", MSC, November 1, 1968.

APPENDIX A

TYPICAL LMP & CDR ACTIVITIES DURING FIRST LM ENTRY

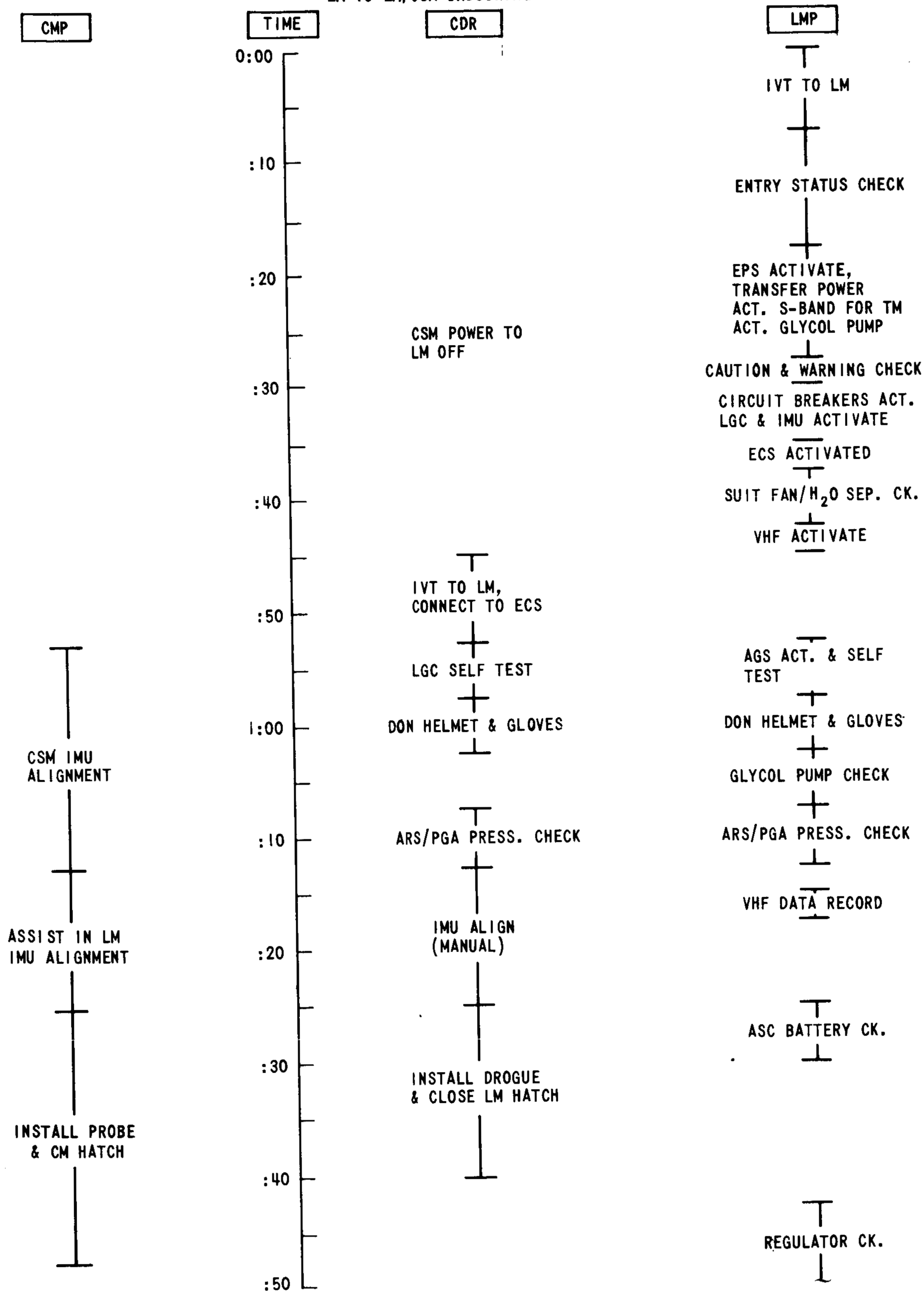


APPENDIX A (CONTINUED)

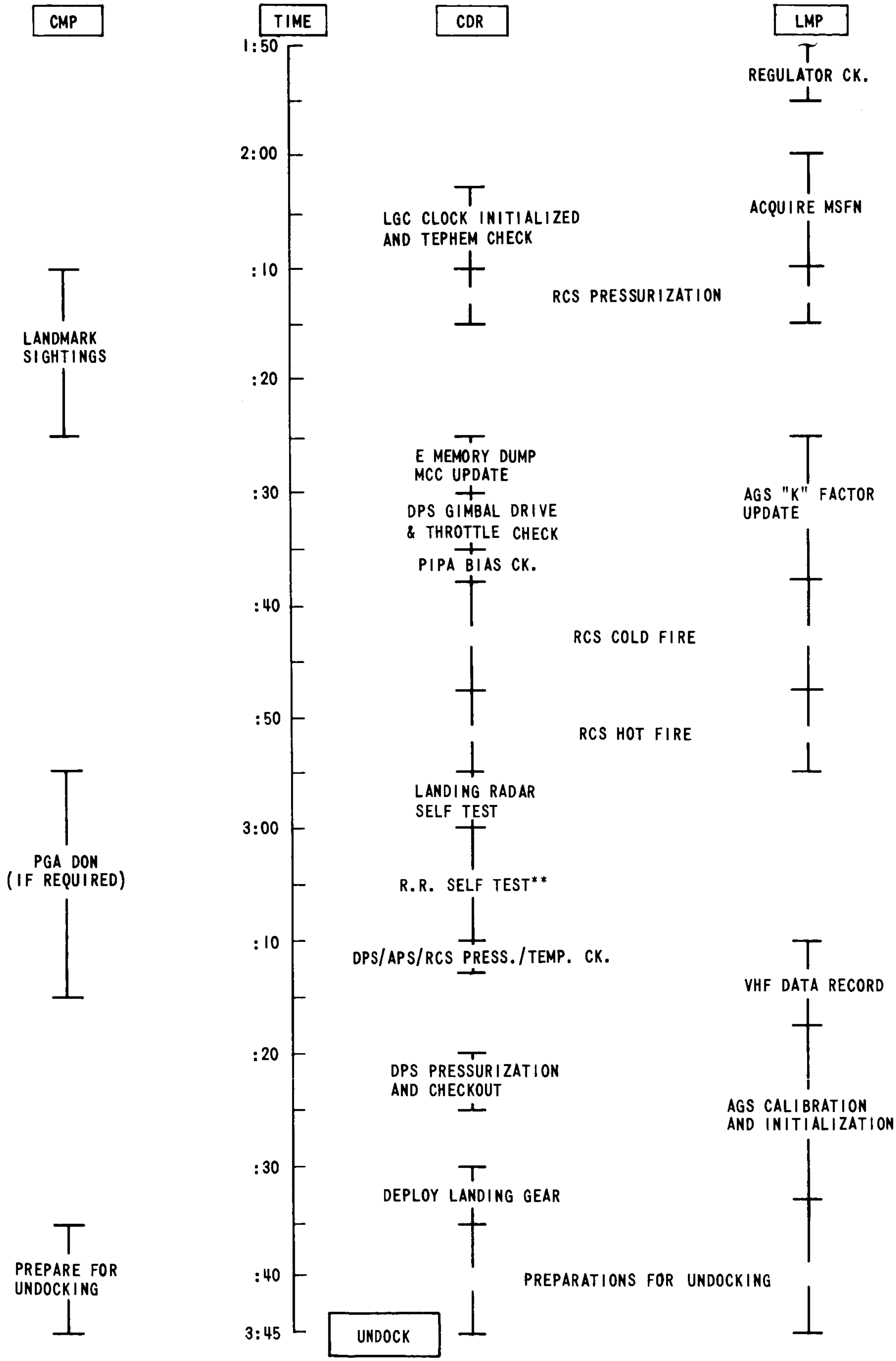
TIME	CDR	LMP
2:00		DEPLOY S-BAND ANTENNA
		S-BAND COMMUNICATION CHECKOUT
:10		
:20		COMMENCE SUBLIMATOR DRY OUT & LM POWER DOWN - CONTINUE S-BAND COMMUNICATION CHECKS IF REQUIRED
:30		
:40		
:50		MSFN VERIFIES DRYOUT
		IVT TO CM
3:00	INSTALL CM HATCH	
:10		

APPENDIX B

TYPICAL CREW ACTIVITIES FROM LMP SECOND ENTRY INTO LM TO LM/CSM UNDOCKING

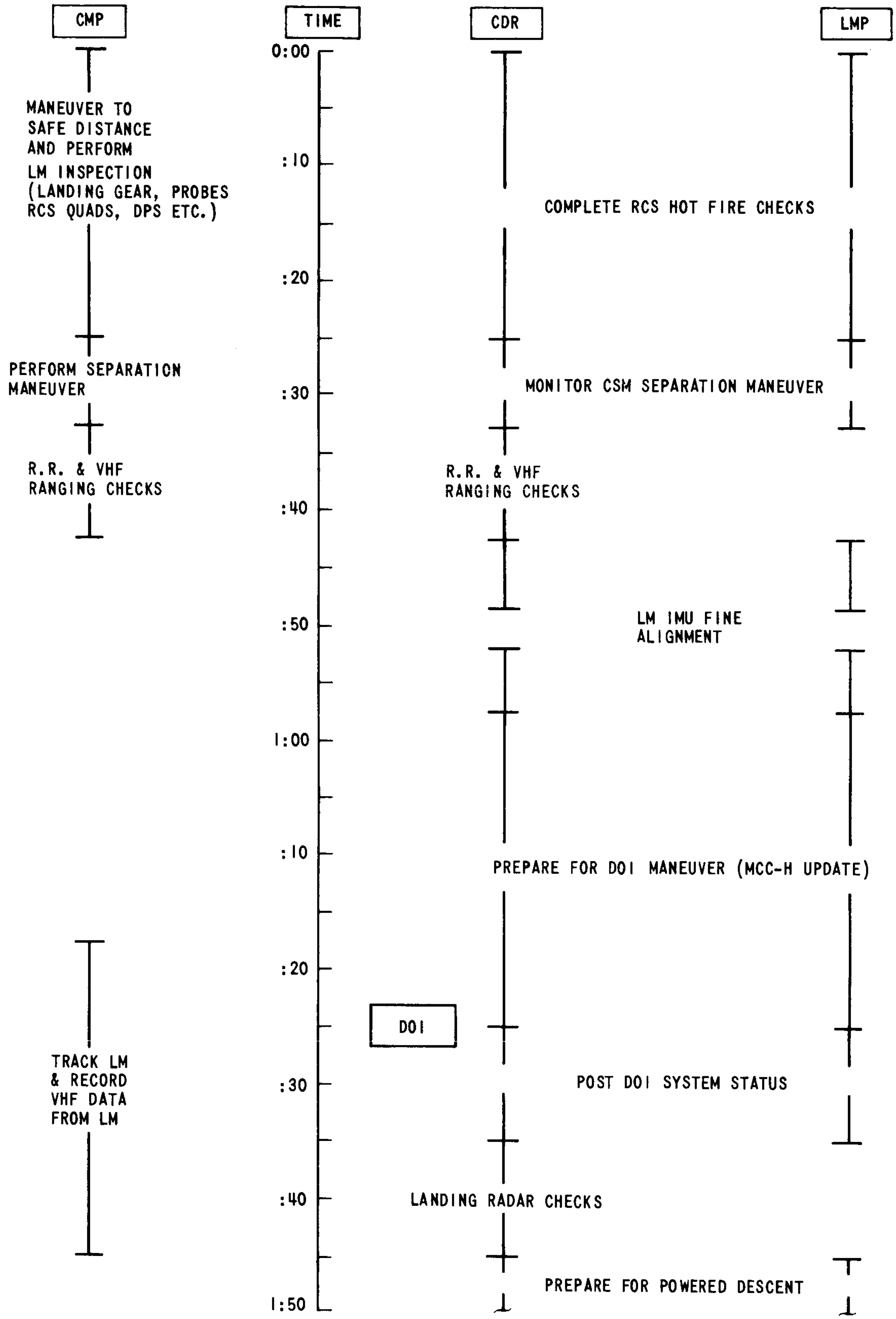


APPENDIX B (CONTINUED)

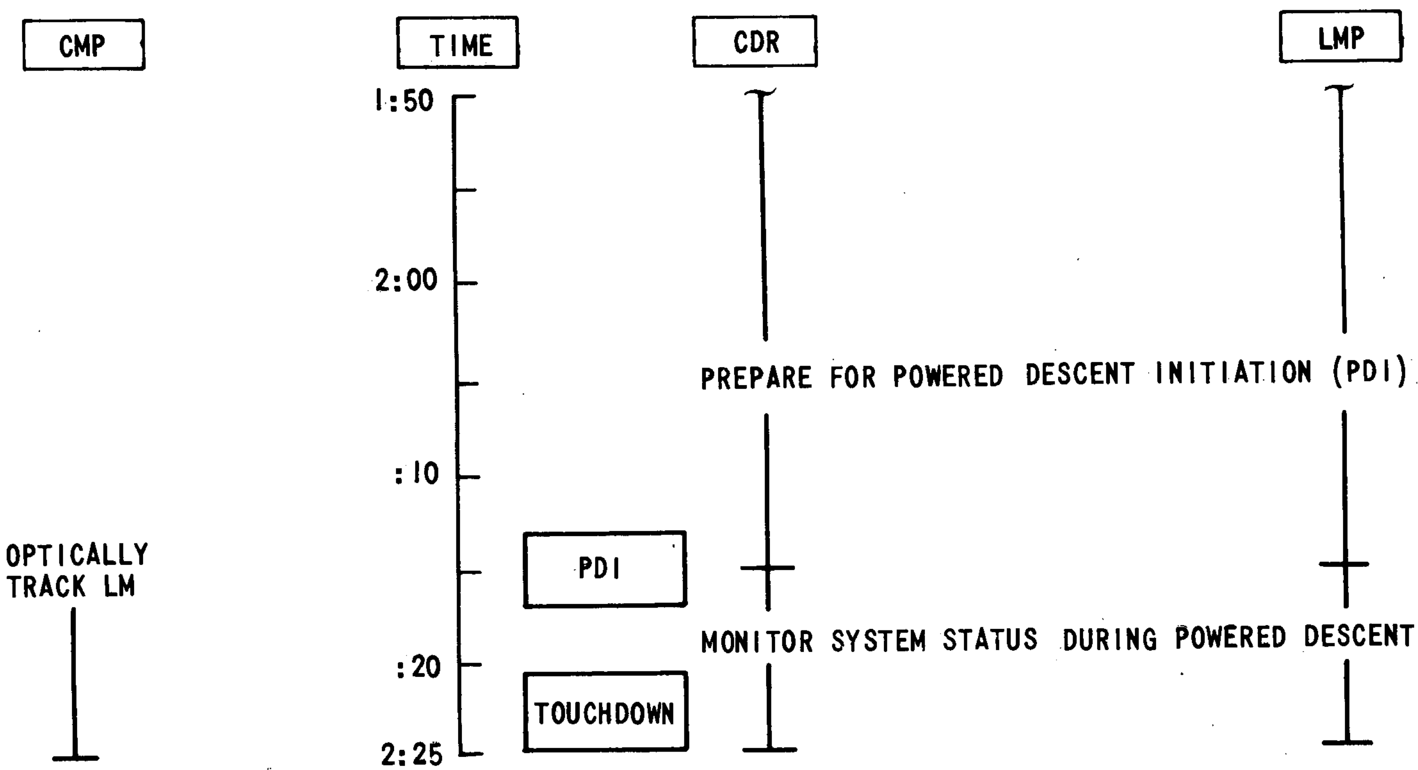


**THIS MAY BE DELAYED UNTIL AFTER UNDOCKING

APPENDIX C
TYPICAL CREW ACTIVITIES AFTER UNDOCKING TO
TOUCHDOWN ON THE LUNAR SURFACE



APPENDIX C (CONTINUED)



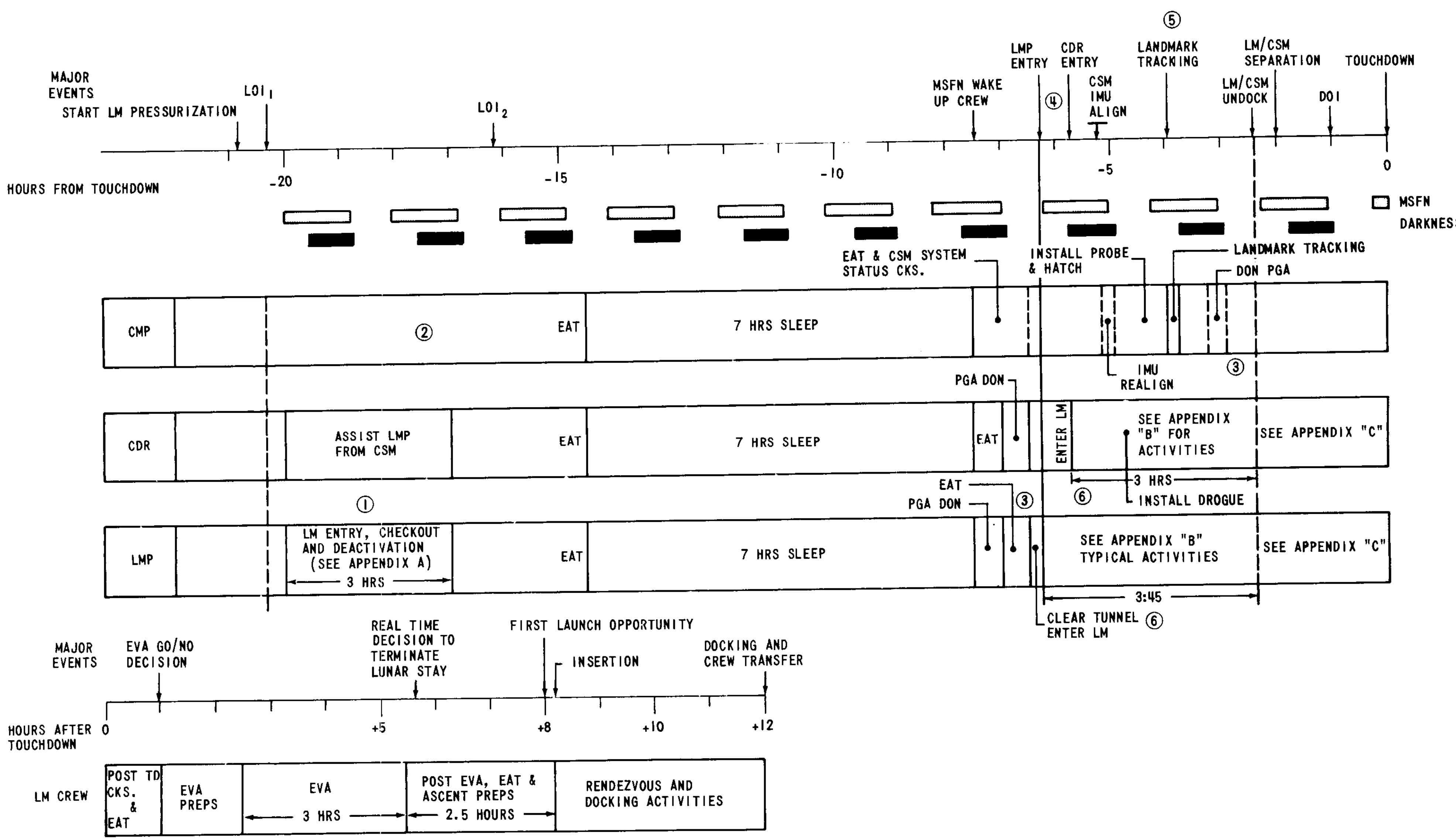


FIGURE-1 PLAN 1 - SPLIT LM CHECKOUT IN LUNAR ORBIT

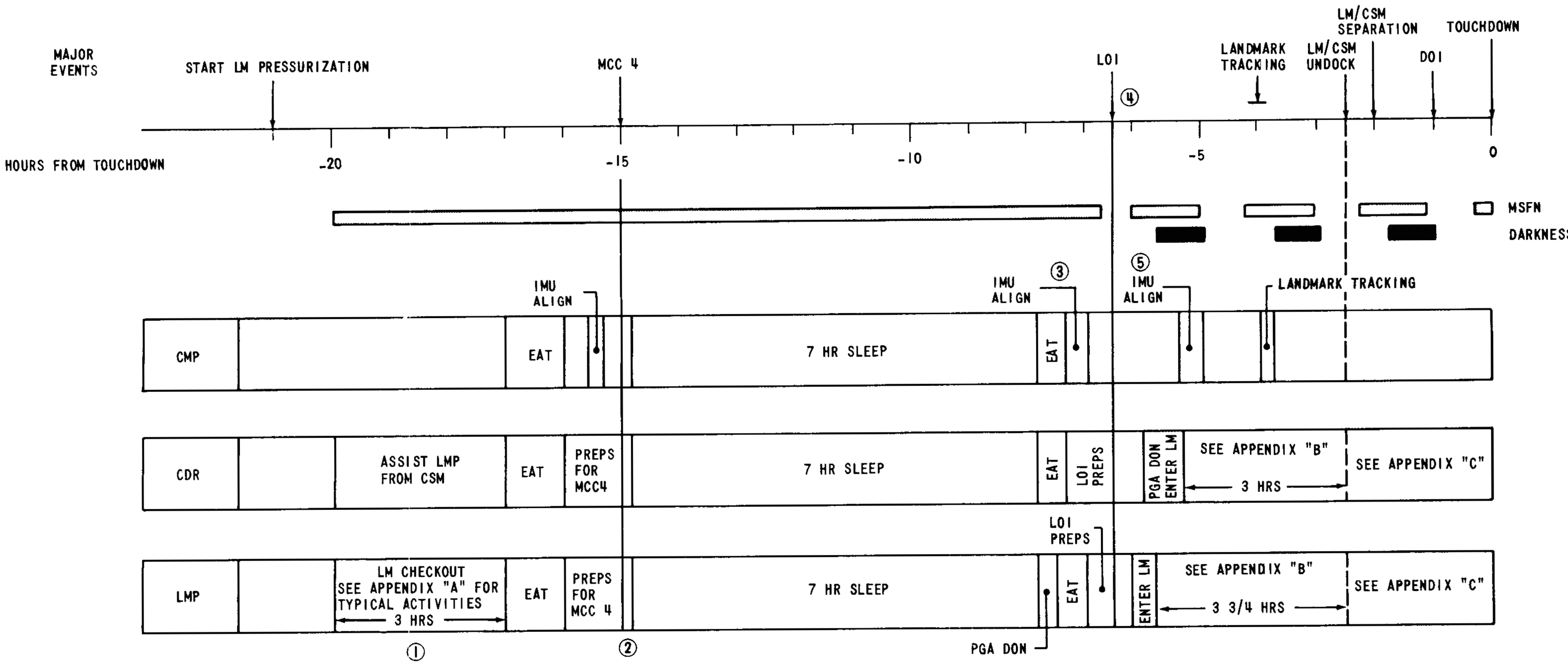


FIGURE 2 - PLAN 2 - PRE-LOI LM CHECKOUT

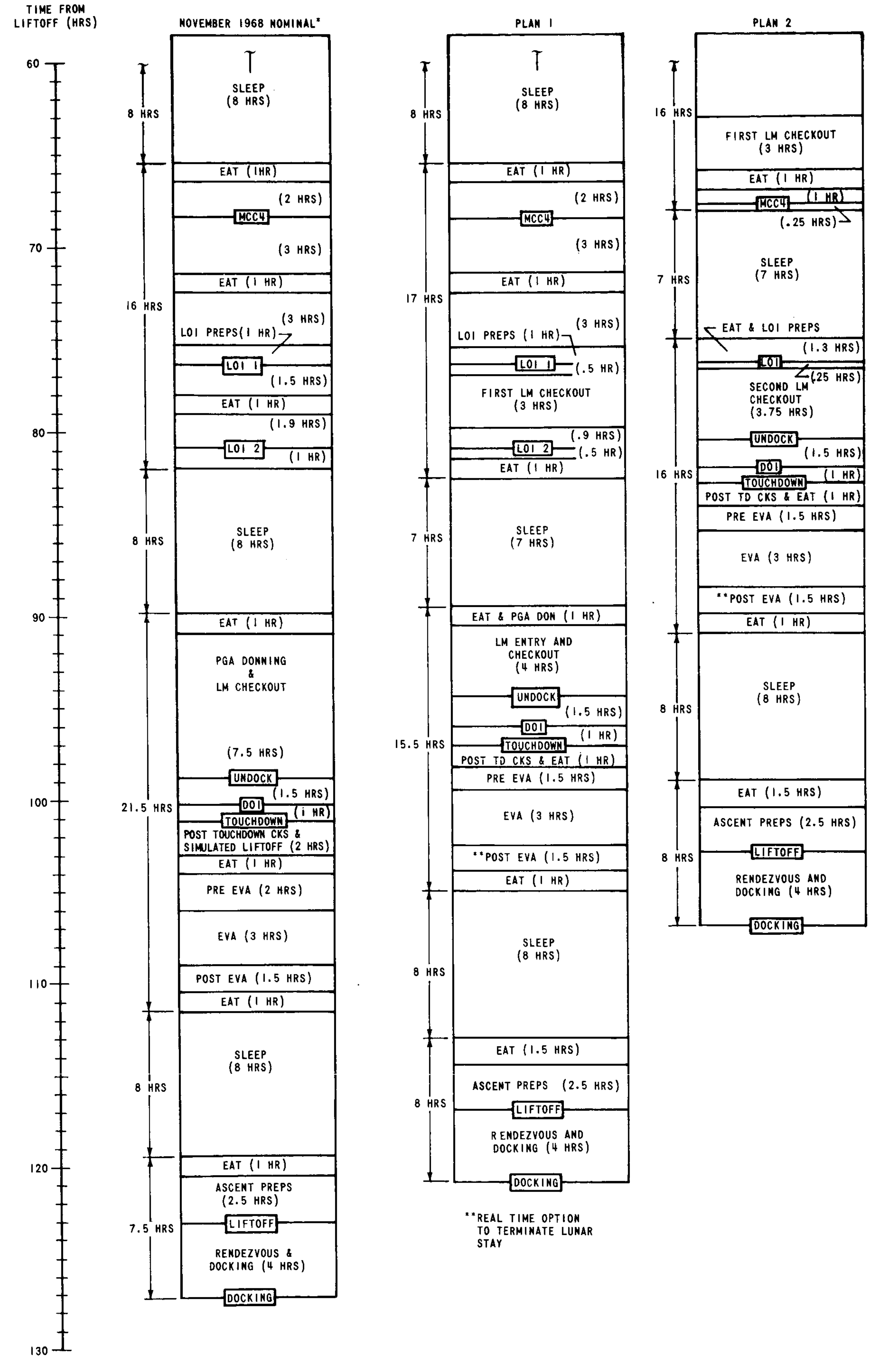


FIGURE 3 - COMPARISON OF NOVEMBER, 1968 TIMELINE AND PROPOSED TIMELINES FOR THE FIRST LUNAR LANDING MISSION

BELLCOMM, INC.

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From: R. E. Driscoll

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